MINERALOGICAL AND PHYSICAL CHARACTERISTICS OF TILL IN MORAINES OF LASALLE COUNTY, ILLINOIS[1]

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ABSTRACT

North-south-trending and arcuate lobate moraine systems occur in LaSalle County. The till of the arcuate system is characterized and distinguishable by relatively coarse texture, high magnetic susceptibility, carbonate, and zirconium contents, as compared with the north-south moraine system. The arcuate system seems to be particularly influenced by Ordovician and Silurian rocks. Illite is the dominant clay mineral of all tills. Iron-rich chlorite is markedly oxidized in the more permeable tills of the arcuate system.

PURPOSE AND OBJECTIVES

The investigation described here was undertaken after detailed soil mapping of LaSalle County was completed. In contrast to most of Illinois, the relatively thin veneer of loess overlying till in this area makes it imperative to correctly identify the texture of till when classifying soils. Samples of calcareous till were taken from 1 to 2 ft below soil profiles in calcareous till of the moraines (fig. 1) in an effort to characterize certain of their physical and chemical properties and to determine if the moraines had unique mineralogical characteristics. Winters and Wascher (1935) and Wascher and Winters (1938), in previous studies of till in northeastern Illinois, found great variability in texture and also determined that differences in texture were not coincident with moraine boundaries.

GLACIAL GEOLOGY

Four recessional Tazewell (Woodfordian) moraines, first described by Leverett (1899), are festooned across LaSalle County, Illinois (fig. 1 and 3). Among these

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moraines there is sufficient topographic evidence to delineate Middle and Inner Cropsey Moraines and Outer and Inner Marseilles Moraines. On a recent map, Leighton and Brophy (1961) renamed some of these moraines. The undifferentiated Cropsey moraine of northwestern LaSalle County is called El Paso moraine, the Farm Ridge Moraine north of the Illinois River is called Cropsey moraine, and the Middle Cropsey Moraine of southwestern LaSalle County is called Mount Palatine Moraine by Leighton and Brophy. Because the nomenclature of these moraines derives in large part from relationships and evidence found beyond the limits of LaSalle County, we shall not attempt to reconcile the naming of these moraines except where evidence is at hand from LaSalle County that indicates there is miscorrelation. These moraines may be considered late Tazewell in that the Minooka Moraine, which marks the boundary of Cary glaciation, is about 10 miles east of Marseilles Moraine.

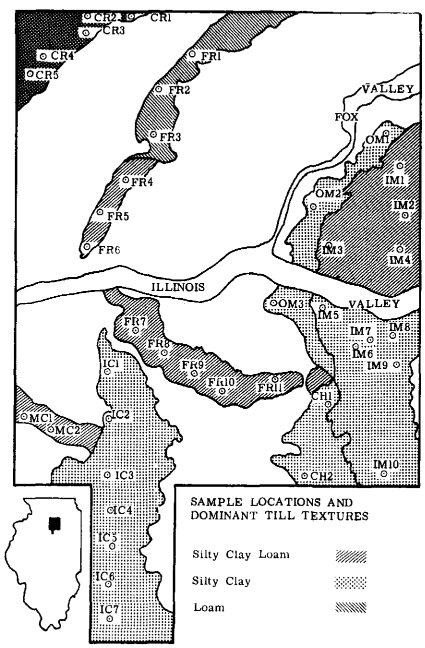

FIGURE 1. Sampling sites and texture of till in moraines of LaSalle County. Refer to figure 3 for moraine names. Note that texture of Cropsey undifferentiated moraine is both silty clay loam and loam.

The configuration of the moraines suggests two principal lobate forms. One, represented by the Marseilles and Inner Cropsey Moraines, is rather broad, the moraines trending almost north-south across the county. The other, represented by the Farm Ridge, Middle Cropsey, and, Cropsey undifferentiated Moraines, has a tight, arcuate form, the axis of which follows the Illinois River Valley.

The moraines rise from 50 to 160 ft above rather flat ground moraine and extensive younger lacustrine deposits that occur in the intermorainal areas. Loess ranges from 30 to 60 inches thick on the Cropsey and Farm Ridge Moraines. From 20 to 40 inches of loess occurs on the Marseilles and Chatsworth Moraines, indicating that about 20 inches of loess was laid down before these moraines were deposited. Willman and Payne (1942) describe a black organic band near the base of the loess associated with Farm Ridge moraine northwest of Ottawa and suggest that it may represent a period of weathering and humus accumulation preceding deposition of loess found on the Marseilles Moraine.

METHODS

Mechanical analyses.—Size distribution was determined by pipette analysis.

Color.—The Munsell system was used to characterize air-dry and moist samples.

Chemical analysis.—Iron and zirconium content of the total sample was determined by X-ray spectrographic analysis, using ground samples pressed into pellets. Potassium content of selected clay-size samples was determined on samples fused in lithium tetraborate. Content of the element in question was estimated from standard curves erected from National Bureau of Standards samples and standards prepared by the addition method. Calcium carbonate equivalent was determined using gravimetric determination of carbon dioxide evolved by warm acid digestion and adsorbed on Mikobite. Alkali-extractable silica and alumina were determined on hydrogen-saturated clays using the method of Hashimoto and Jackson (1960).

Magnetic susceptibility.—Magnetic susceptibility was determined on total sample using a Faraday balance. Mercury (II) tetrathiocyanatocobaltate (II) was used as a standard (16.44×10^{-6} cgs, 20°C).

X-ray diffraction.—Diffraction patterns from 2° to 30° two-theta of clay minerals were obtained from sodium-, potassium-, and strontium-saturated parallel-oriented specimens on glass slides. Diffraction patterns of heated (550°C for 30 min) and glycolated samples were also obtained. Iron-rich chlorite is identified on the basis of weak first- and third-order basal reflections and its instability to heat treatment (Brindley, 1961). Dolomite- and calcite-peak height intensities were obtained from ground total samples.

Heavy minerals.—Amount of heavy minerals in the sand fraction (50–250 μ) was obtained from separates after centrifugation in bromoform. Prior to removal of heavy minerals, the sand fraction was treated with hot acetic acid to remove carbonates (principally calcite).

PHYSICAL CHARACTERISTICS

The textural characteristics and color of the tills in the moraines are listed in Table 1 and the sample locations and textures are given in figure 1. Brief remarks describing the individual moraines follow.

Inner Marseilles Moraine.—Color of till in the Inner Marseilles Moraine is most commonly gray brown to dark gray brown in the moist state. When dry, the till is gray to light olive gray or light yellowish brown. Texture of Inner Marseilles till ranges from clay to silty clay loam.

Outer Marseilles Moraine.—Color of till in the Outer Marseilles Moraine is gray brown to light olive brown in moist condition. Texture of the till is clay or silty clay.

Chatsworth Moraine.—Color of till in the Chatsworth Moraine is light brownish gray to gray brown when dry. Texture of the two samples from the Chatsworth moraine were clay and silty clay.

Farm Ridge Moraine.—The segment of the Farm Ridge Moraine north of the Illinois River occurs as two distinct units. The southernmost five miles of the moraine is silty clay and silty clay loam in texture and has a color of pale brown or gray brown when moist and light gray or light brownish gray when dry. In the northern segment, texture is loam or silt loam and color is brown when moist and pale brown or light yellowish brown when dry. South of the Illinois River, the Farm Ridge Moraine is silty clay loam in texture and, in color, is light olive brown to olive brown when moist and light gray to light brownish gray when dry.

Inner Cropsey Moraine.—Till from the Inner Cropsey Moraine is gray brown to light olive brown when moist and light gray to light brownish gray when dry. Silty clay is the dominant texture.

TABLE 1

Texture and color of tills in LaSalle County, Illinois

Sample No.	Sand .05–2 mm	Silt .002–.02 mm	Silt .02–.05 mm	Silt .002–.05 mm	Clay <.002 mm	Textural class (USDA)	Color Moist	Color Dry
				Inner Marseilles Moraine				
1M1	13.6	45.7	18.7	64.4	22.0	Silt loam	2.5Y5/4	2.5Y6/4
1M2	14.7	39.3	17.0	56 3	29.0	Silty clay loam	10YR5.5/3	10YR6.5/3
1M3	12.5	37.9	11.9	49.8	37.7	Silty clay loam	2.5Y4.5/2	2.5Y6/2
1M4	15.5	35.7	20.4	56.1	28.4	Silty clay loam	10YR5/3	10YR6/3
1M5	4.7	28.1	5.4	33.5	61.8	Clay	2.5Y4/2	2.5Y6/2
1M6	17.7	34.6	11.3	45.9	36.4	Silty clay loam	2.5Y5/3	5Y6/3
1M7	14.7	34.3	12.1	46.4	38.9	Silty clay loam	2.5Y4/2	5Y6/1
1M8	1.6	29.4	6.4	35.8	62.6	Clay	2.5Y4.5/2	5Y6/1
1M9	13.7	36.6	11.7	48.3	38.0	Silty clay loam	2.5Y5/2	2.5Y6.5/2
1M10	10.5	34.8	10.0	44.8	44.7	Silty clay	2.5Y4.5/2	5Y6/2
				Outer Marseilles Moraine				
OM1	6.0	36.8	9.2	46.0	48.0	Silty clay	2.5Y5/2	2.5Y6/2
OM2	1.2	34.1	4.7	38.8	60.0	Clay	2.5Y5/2	5Y7/2
OM3	1.4	33.6	5.6	39.2	59.4	Silty clay	2.5Y5/3	2.5Y6/2
				Chatsworth Moraine				
CH1	1.6	22.7	4.3	27.0	71.4	Clay	2.5Y5/2	5Y6/2
CH2	8.6	39.4	8.4	47.8	43.6	Silty clay	5Y6/2	2.5Y4.5/2
				Farm Ridge Moraine				
FR1	28.8	33.0	18.0	51.0	20.2	Silt loam	10YR5/3	10YR6.5/3
FR2	30.5	30.1	20.4	50.5	19.0	Loam	10YR5/3	10YR6/3
FR3	33.7	31.8	23.1	54.9	11.4	Silt loam	10YR5/3	10YR6/4
FR4	27.7	32.1	22.9	55.0	17.3	Silt loam	10YR4.5/3	10YR6/3
FR5	10.7	37.7	9.9	47.6	41.7	Silty clay	2.5Y5/2	2.5Y6/2
FR6	18.9	36.6	13.3	49.9	31.2	Silty clay loam	10YR5/3	2.5Y6.5/2
FR7	14.7	33.4	12.3	45.7	39.6	Silty clay loam	2.5Y4/4	2.5Y6.5/2
FR8	16.2	36.3	13.1	49.4	34.4	Silty clay loam	2.5Y5/4	2.5Y6.5/2
FR9	18.0	38.9	15.7	54.6	27.4	Silty clay loam	2.5Y5/3	2.5Y6/4
FR10	19.7	34.0	15.1	49.1	31.2	Silty clay loam	10YR5/2	2.5Y6/2
FR11	22.2	33.4	14.6	48.0	29.8	Silty clay loam	2.5Y5/4	2.5Y6.5/2
				Inner Cropsey Moraine				
IC1	10.4	34.9	15.7	50.6	39.0	Silty clay loam	2.5Y5/4	2.5Y6.5/2
IC2	11.1	32.1	10.7	42.8	46.1	Silty clay	2.5Y5/4	2.5Y6.5/2
IC3	9.6	33.3	10.0	43.3	47.1	Silty clay	2.5Y5/4	2.5Y6.5/2
IC4	9.9	33.6	10.0	43.6	46.5	Silty clay	5Y5/3	2.5Y6.5/2
IC5	11.7	33.6	11.0	44.6	43.7	Silty clay	2.5Y5/3	2.5Y6/2
IC6	8.2	35.1	11.8	46.9	44.9	Silty clay	2.5Y5.5/2	2.5Y7/2
IC7	7.0	36.6	8.3	44.9	48.1	Silty clay	2.5Y5/3	2.5Y6/2
				Middle Cropsey Moraine				
MC1	19.4	34.1	12.7	46.8	33.8	Silty clay loam	2.5Y5/3	2.5Y6/3
MC2	21.2	33.1	13.5	46.6	32.2	Clay loam	2.5Y3/4	2.5Y6.5/2
				Cropsey (Undifferentiated) Moraine				
CR1	24.9	35.6	15.1	50.7	24.4	Loam	10YR4/3	10YR6/3
CR2	37.2	30.6	19.2	49.8	13.0	Loam-silt loam	10YR5/3	10YR6/3
CR3	19.2	37.7	13.6	51.3	29.5	Silty clay loam	10YR5/3	10YR6/3
CR4	19.9	39.3	13.8	53.1	27.0	Silty clay loam	10YR5/3	10YR6.5/3
CR5	25.4	35.5	15.0	50.5	24.1	Loam-silt loam	10YR5/3	10YR6/3

Middle Cropsey Moraine.—Color of till from the Middle Cropsey Moraine is light olive brown to olive brown when moist and light brownish gray to light yellowish brown when dry. Texture is dominantly silty clay loam.

Cropsey Moraine-Undifferentiated.—Color of till in the undifferentiated Cropsey Moraine from northwestern LaSalle County is dark brown to brown when moist and pale brown when dry. Texture varies from loam to silty clay loam.

Discussion.—Although no clear-cut textural divisions among the moraines are apparent, no moraine varies in texture greater than two textural groups, except in the case of the north and south segments of the Farm Ridge Moraine, which appear to reflect differences in bedrock. In general, textures are coarser north of the Illinois River, probably as a result of erosion of Ordovician sandstones, e.g. St. Peter. The Inner Cropsey Moraine is remarkable because of its uniform texture from north to south, as is the case with the Farm Ridge Moraine south of the Illinois River. Hue of the relatively coarse-textured tills is decidedly redder than the fine-textured tills, suggesting the greater presence of hematite and high state of oxidation. The fine-textured tills have low chroma and are gray colored. An idea of the range of textures encountered in the tills can be gained from accumulation curves plotted in Fig. 2.

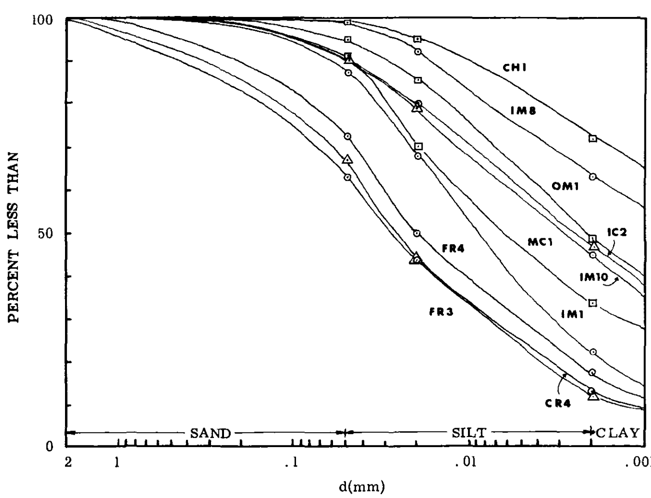

FIGURE 2. Accumulation curves for mechanical analyses of selected samples.

CLAY MINERALOGY

Diffractograms representative of samples from the moraines are superimposed on a moraine map (fig. 3). Diffraction data and potassium content (table 2) indicate that the crystalline clay mineral suite is composed principally of illite. Using 8.5 per cent as a modal illite (Weaver, 1965), the tills contain from 50 to 70 per cent illite. The limited data in table 2 suggest that north-south trending moraines have slightly higher mica contents or that the mica contained in these tills is derived from more potash-rich sources. There is no indication of mica degradation in the diffraction data. Other subtle differences occur in mineralogy between the moraines. The more abundant occurrence of iron-rich chlorite in the fine-textured tills of the Marseilles, Chatsworth, and Inner Cropsey Moraines is apparent from the intensity of the 7A peak in figure 3.

An evaluation of illite to chlorite net peak gives ratios of less than 5 to 1 for the north-south systems and 5 to 8 to 1 for the arcuate Illinois River lobe represented by the Cropsey and Farm Ridge Moraines. There appears to be a relationship of clay minerals with texture, represented by relatively more chlorite in the fine-textured tills. This relationship is borne out by a plot of the ratio of net intensities of the 10A to 7A reflections as a function of amount of particles less than 2 μ in the sample (fig. 4). The 10A to 7A ratio as a function of less than 2 μ material is a negative linear correlation, albeit a weak one. This apparent

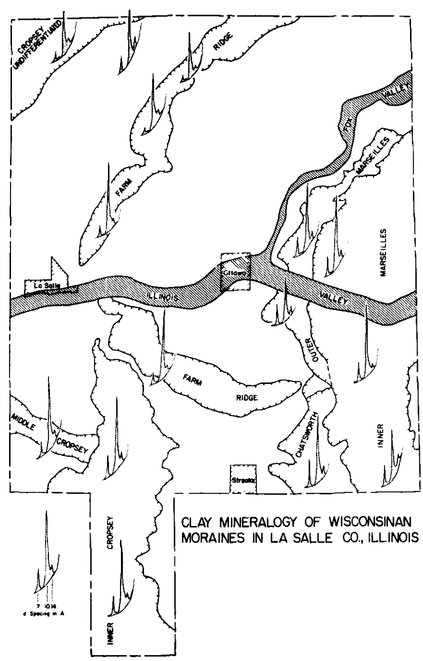

FIGURE 3. Diffractograms from 2° to 14°–2θ (CuK α) for representative samples. Glacial Map of the United States East of the Rocky Mountains (1959) uses Arlington for Cropsey Undifferentiated Moraine.

TABLE 2

Potassium content, calculated illite content, and alkali extractable silica and alumina of the clay-size fraction

Sample No.	K_2O %	Illite* %	SiO_2 %	Al_2O_3 %
IM7	5.86	69	1.8	1.5
OM2	5.24	62	1.3	2.4
CH2	5.43	64	1.5	2.0
FR1	4.80	56	1.7	1.6
FR5	5.35	63	1.5	2.2
IC3	5.29	62	1.9	2.3
MC2	4.90	58	1.7	2.8
CR1	4.83	57	2.5	2.4
CR4	5.22	61	2.1	2.8
Mean N-S		64		
Mean arcuate		59		

*Assuming 8.5% K_2O in illite

decrease in chlorite content in the coarse-textured tills is attributed to oxidation of iron and breakdown of structure. The disruption of the chlorite structure is particularly apparent in the configuration of the (003) reflection at 4.7A, which is markedly weakened and merges as a shoulder on the high-angle side of the (002) mica reflection. Although this oxidation could be attributed to weathering previous to deposition, when the glacier lay to east, before reforming to deposit the arcuate system of moraines, it is more probable that the chlorite is now undergoing oxidation in the more permeable tills.

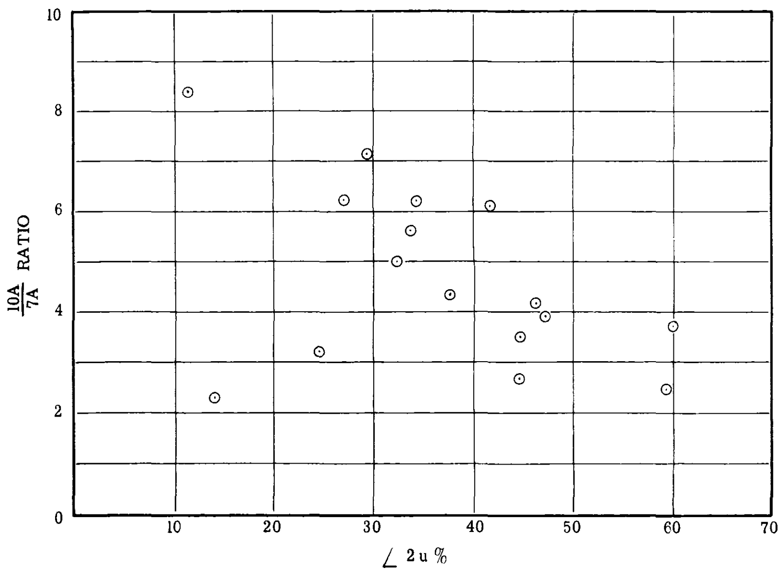

FIGURE 4. Relationship of 10A/7A net intensity ratio to clay-size content of the till.

Kaolinite occurs in only trace amounts, if at all. No second order peak (002) was observed and the amount of silica and alumina dissolved at 500°C indicates less than five percent kaolinite present if these analyses are allocated to kaolinite. In addition, very minor amounts of expandable minerals are present in interlayer positions.

CARBONATE CONTENT

Percent carbonate, calculated as calcium carbonate equivalent (table 3), is closely related to texture. Greatest amount of carbonate rock occurs in loam- and silt-loam-texture tills except for some areas of fine-textured till in the Inner Marseilles Moraine. Diffraction data for calcite and dolomite indicate that dolomite is the preponderant carbonate mineral and is probably derived from Silurian and Ordovician dolomites to the northeast of LaSalle County. High carbonate contents north of Illinois River are attributable to glacial erosion of local Ordovician dolomite and limestone outcrops beneath the drift. Krumbein (1933), Horberg (1956), and Willman et al. (1963), as well as Wascher and Winters (1938), report higher carbonate contents for Wisconsin-age till materials in northeastern Illinois than in drift to the east and south. It is interesting to note that soils developed in the more impermeable, fine-textured tills that are low in carbonates are leached less deeply than those in the relatively coarse-textured and more permeable tills high in carbonates (Wascher and Winters, 1938).

TABLE 3

Elemental and mineralogical data

Sample No.	Fe_2O_3 %	ZrO_2 %	$CaCO_3$ %	Calcite* net cps	Dolomite** net cps	Mag. Sus. cgs	Soluble minerals %	Heavy minerals %
				Inner Marseilles Moraine				
IM1	4.47	.015	39.34	23	519	7.4	77.5	44.91
IM2	4.50	.013	34.79	43	424	7.7	8.1	8.03
IM3	5.26	.015	31.93	16	159	7.6	24.8	n.d.
IM4	4.48	.013	33.84	25	514	7.3	59.3	1.78
IM5	5.55	.012	20.15	19	137	6.1	43.6	0.77
IM6	5.32	.013	23.88	17	347	7.0	n.d.	n.d.
IM7	5.13	.015	25.24	7	406	6.2	7.7	n.d.
IM8	5.72	.018	17.74	70	97	6.2	29.3	1.44
IM9	5.03	.013	28.20	39	356	7.4	n.d.	n.d.
IM10	6.33	.021	12.37	137	130	6.2	34.8	2.00
				Outer Marseilles Moraine				
OM1	6.27	.012	18.24	20	163	6.0	24.5	5.79
OM2	5.59	.013	16.19	42	166	5.9	3.1	0.64
OM3	5.76	.016	15.25	0	564	4.8	22.7	2.67
				Chatsworth Moraine				
CH1	6.64	.012	13.64	18	85	6.1	64.1	n.d.
CH2	5.61	.013	11.10	15	187	5.9	27.6	1.34
				Farm Ridge Moraine				
FR1	3.87	.016	34.54	32	718	8.1	n.d.	n.d.
FR2	3.69	.017	33.66	33	714	9.1	10.0	1.77
FR3	3.23	.017	39.93	17	591	8.6	7.1	1.58
FR4	3.49	.015	21.70	28	729	8.5	11.4	2.02
FR5	5.54	.013	22.42	17	305	7.6	20.0	3.70
FR6	4.60	.014	28.65	n.d.	n.d.	7.3	n.d.	n.d.
FR7	5.31	.013	23.20	33	315	7.1	16.9	1.92
FR8	4.85	.014	27.33	18	237	6.8	13.8	1.97
FR9	4.77	.014	27.63	10	415	7.3	15.8	1.52
FR10	4.97	.018	34.36	10	353	7.4	12.5	2.03
FR11	5.21	.016	24.88	0	564	6.6	8.6	1.13
				Inner Cropsey Moraine				
IC1	5.40	.018	21.99	12	221	6.6	15.3	1.71
IC2	5.58	.014	20.72	27	246	6.7	19.8	1.49
IC3	5.80	.017	19.13	40	331	6.3	n.d.	n.d.
IC4	6.02	.015	14.10	0	187	6.0	n.d.	n.d.
IC5	5.37	.014	21.49	38	258	6.6	14.2	1.59
IC6	5.50	.015	19.82	5	162	4.9	19.0	1.22
IC7	5.74	.014	17.28	22	141	6.2	13.5	2.75
				Middle Cropsey Moraine				
MC1	4.57	.014	28.47	43	331	7.2	12.7	1.58
MC2	4.69	.016	25.98	40	334	7.1	12.3	1.65
				Cropsey (Undifferentiated) Moraine				
CR1	4.27	.017	25.88	16	358	9.4	10.6	1.84
CR2	3.19	.015	25.61	34	524	9.3	n.d.	n.d.
CR3	4.86	.017	22.86	13	369	8.3	13.0	1.60
CR4	4.41	.017	26.84	65	437	7.7	9.5	1.86
CR5	3.84	.016	31.09	35	410	8.0	n.d.	n.d.

*(104) reflection.
**(104) reflection.

ELEMENTAL ANALYSIS

Amounts of iron and zirconium (table 3) also follow a textural relationship. Greatest iron content is associated with fine-textured samples and it can be inferred that much of the iron occurs in the clay-size fraction. Slight but perceptible increase in zirconium content occurs in the loam and silt-loam samples, which is undoubtedly a reflection of more zircon contributed by greater silt-sized mineral content; however, the content of zirconium is low compared to that in the loess of northern Illinois (Alexander et al., 1962).

MAGNETIC SUSCEPTIBILITY

As with all the parameters measured, magnetic susceptibility (table 3) varies with texture and, therefore, mineralogy. Lowest susceptibility values are associated with clay and silty clay loam textures. These samples also contain the highest amounts of iron, creating a relationship wherein magnetic susceptibility decreases with increasing iron content. Evidently the colloidal iron is present in species having low susceptibility; thus, the fine-textured samples have low susceptibility in contrast to higher susceptibilities contributed by iron-bearing silt-size minerals like magnetite, ilmenite, pyroxenes, and amphiboles in the loam and silt loam texture samples. Magnetic susceptibility of the sand fraction (table 4) indicates that it has relatively low value and high variability.

TABLE 4

Magnetic susceptibility of sand fractions (50–250 μ)

Sample No.	Sand %	Magnetic susceptibility X x10^{-6} cgs
IM3	12.5	7.7
IM7	14.7	4.0
IM10	10.5	10.6
OM2	1.2	11.5
OM3	1.4	35.2
IC3	9.6	4.5
IC6	8.2	16.5
MC1	19.4	6.0
CR1	24.9	1.6
CR3	19.2	0.6
CR4	19.9	1.1

HEAVY MINERALS

The amount of heavy minerals varies quite markedly within and among the textural classes encountered (table 2). Amount of acid-soluble minerals is lower (on the order of 10 to 12 per cent) in the coarse-textured samples. There appear to be significantly more soluble minerals, principally calcite in view of the acetic acid treatment, in the 50- to 250-μ fraction of the Marseilles and Chatsworth Moraines; consequently, these samples contain very little or are almost devoid of heavy minerals because of low amount of sand-size material.

Cursory examination of the heavy mineral fraction from selected samples, taken both north and south of the Illinois River and from each moraine, indicated that no outstanding mineralogic differences occur among the samples. The largest species of all of the samples are rounded fragments of fine-grained limonite-rich rocks. Abundant red spherules of oolitic hematite of about 200 μ occur in varying proportion among the samples, as do conodonts. Cleavage fragments of hornblende, subangular ilmenite, angular magnetite, pink and red garnet, and epidote are the more prominent minerals.

SUMMARY

Moraines of LaSalle County can be separated into two systems on the basis of shape of the trace of the moraine crest. One system is characterized by a north-south trend, and is represented by the Marseilles, Chatsworth, and Inner Cropsey Moraines; the other system is characterized by a tight arcuate shape, the axis of which approximates the alignment of the Illinois River Valley and is represented by the Farm Ridge, Middle Cropsey and Cropsey undifferentiated Moraines. Subtle differences in mineralogy occur between the two systems. The arcuate system is influenced by Ordovician source rocks and deposits underlying and to the northeast of the study area that give relatively coarser textures (loam and silt loam) north of Illinois River. In contrast to the north-south moraines, the arcuate moraines are characterized by low chlorite and iron contents, and high magnetic susceptibility, carbonate, and zirconium content. Iron-rich chlorite is markedly oxidized in the more permeable tills. Illite is the dominant clay mineral of all tills, ranging from 50 to 70 per cent. Dolomite is the dominant carbonate mineral. Differences in mineralogical characteristics of the two moraine systems are attributable to differences in lithology between Silurian, Ordovician, and Pennsylvanian rocks now buried from 25 to 300 ft below the surface of the drift in the immediate area.

Correlation of the Farm Ridge Moraine north and south of the Illinois River, where the Inner Cropsey Moraine forms a reentrant, seems justifiable in light of similarities in mineralogy. The basis for the mapping of the Inner and Outer Marseilles and Chatsworth Moraines, which are essentially identical mineralogically, remains a matter of tracing moraine crests.

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